An Evaluation of Alternative Qualifying Criteria for Energy Star Windows: May 8, 2002

U.S. Department of Energy
Office of Building Technology, State and Community Programs

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1.0 Background/Objectives

1.1 Energy Star Program

Energy Star is a voluntary partnership between the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and industry. Energy Star, at both DOE and EPA, is based on legislative mandates to implement voluntary, non-regulatory programs to promote products that are substantially more efficient than required by Federal standards (the DOE Energy Star program originated with Section 127 of the Energy Policy Act of 1992 (EPACT), and the EPA Energy Star program originated with Section 103 of the Clean Air Act amendments of 1990). The base criteria under EPACT requires DOE to establish voluntary energy efficiency product programs that serve to increase the technical energy performance potential of products, are cost-effective for the consumer, save energy and thus reduce green house gas emissions. Criteria used by EPA under the Clean Air Act are similar but reflect a greater emphasis on reducing green house gas emissions.

The primary objective of the partnership is to expand the market for energy-efficient products. EPA and DOE use the Energy Star label to recognize and promote the most energy-efficient subset of the market. The label is a simple mechanism that allows consumers to easily identify the most energy-efficient products in the marketplace.
In developing specifications for the Energy Star label, EPA and DOE consider several key factors, including:

- Energy and environmental savings based on unit sales aggregated at the national level;
- Assurance that the efficient product offers the same or better overall performance as a less efficient product;
- Assurances that the technologies or processes required for a more efficient product are commercially available and nonproprietary.

1.2 Energy Star Windows

The Energy Star windows program has, since its inception in 1998, successfully promoted the increased use of efficient residential windows in the United States. As a percentage of overall national residential window sales, the number of Energy Star-qualifying windows has risen from less than 5 percent in 1997 to 15 percent in 1999, and has reached an estimated 35 percent level in 2002. These numbers are based on sales and shipment data provided by partners as part of their Energy Star agreement.

The program defines efficient residential windows by setting constraints on their U-factors and Solar Heat Gain Coefficients (SHGCs). A lower U-factor means a window is a better insulator, and a lower SHGC means the window blocks more of the sun’s heat. The lower a window’s U-factor and the higher its SHGC, the more it lowers a building’s heating energy use. The lower a window’s SHGC, the more it lowers the building’s cooling energy use (U-factors have minimal impact on cooling).

1.3 Goals and Changes from March 19, 2002 Report

The stated purpose of this report is to evaluate the Department of Energy’s Final Proposed Energy Star Windows Program criteria. The previous version of this report (March 19, 2002) analyzed the October, 2001 Proposed Energy Star criteria and several proposals, not including the Final Proposed Program or Proposal 8. Additionally, further refinement and corrections in the spreadsheet account for the differences in energy saving results when compared to the March 19, 2002 report.

The Final Proposed Program criteria are being considered to replace the existing Energy Star Windows Program criteria, adopted in 1998. The purpose of the proposed change in Energy Star windows criteria is to upgrade the stringency of the criteria based on changes to state and national building codes and increases in consumer sales of qualifying products. This report addresses potential energy savings from the proposed revisions, several industry proposals and the authors of this study. In the conclusion, we also highlight advantages and disadvantages of each proposal.

More specifically, for each proposal we assessed:

- Potential national and regional energy savings
- Impact on product availability
- Consistency with energy codes
- Energy-related impacts (i.e., on electricity reliability and supply, pollution) within the Central Region of the United States.

The scenarios analyzed include: the 2000 International Energy Conservation Code (IECC), as a reference; the current Energy Star program; the Proposed Program; the Fall 2001 Proposed Program; several alternative proposals offered by industry; and additional alternative proposals developed by the authors of this report, in response to comments received from industry and other sources. The proposals and alternative criteria are described in Table 1 and its accompanying footnotes. Figure 1 shows the new Proposed Energy Star map. The map divides the country in three regions: Northern, Central, and Southern.

Figure 1: Final Proposed Energy Star Map

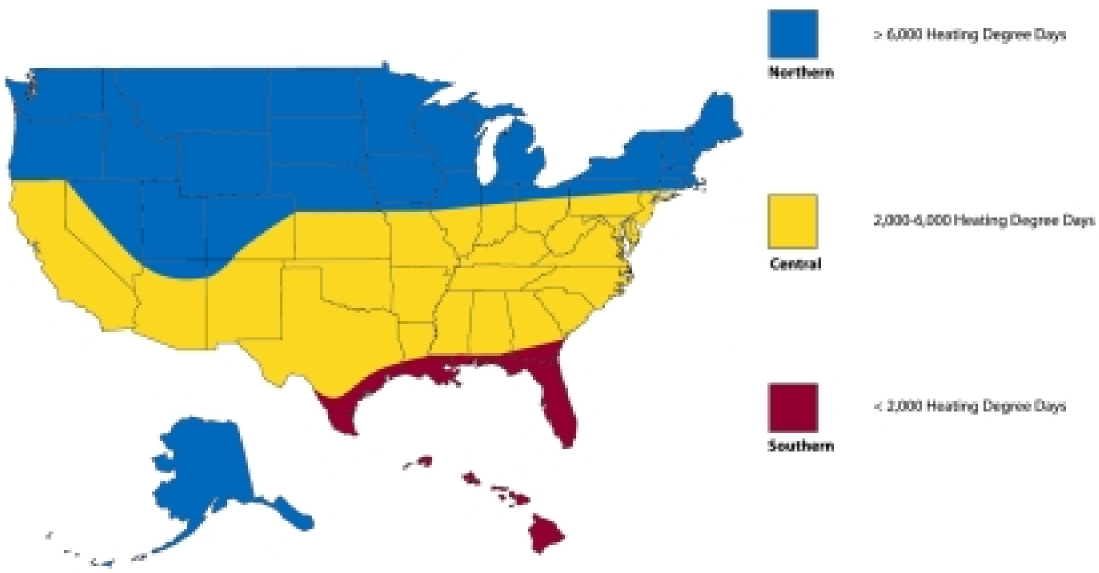


Table 1 lists potential Energy Star criteria requirements by Heating Degree-Days or HDDs. The IECC sets windows efficiency requirements by dividing the United States into climatic regions based on HDDs. The regions were determined to be an effective means to set climate specific requirements for the Energy Star Windows Program. Strict adherence to HDDs would create Energy Star zones that are not continuous, resulting in a patchwork of requirements. To simplify the Energy Star for the average consumer, the zones shown in Figure 1 deviate from the precise HDD contours to create continuous zones, similar to Current Energy Star Windows criteria. Thus, the HDD descriptions in Table 1 are illustrative—not absolute—for all proposals under study. The IECC reference case in contrast, strictly follows HDD contours. The actual HDD distribution is shown in Figure 2, which approximates the regions for the IECC analysis.

Table 1: Energy Star Alternatives and Reference Cases Approximate HDD Climate Zones

Reference/ Proposals	<2000 HDD	2000–3499 (includes CA Central Valley)	3500–5999	6000+
IECC	U≤0.75 SHGC≤0.4	U≤0.5 SHGC≤0.4	U<.4 (U≤0.5 3500 to 3999 HDD) SHGC-Any	U < .35 SHGC – Any
Current Energy Star	U≤0.75 SHGC≤0.4		U≤0.4 SHGC≤0.55	U≤0.35 SHGC- Any
Final Proposed Energy Star	U≤0.65 SHGC≤0.4	U≤0.4 SHGC≤0.4		U≤0.35 SHGC – Any
Original Proposed	U≤0.75 SHGC≤0.4	U≤0.4 SHGC≤0.4		U≤0.35 SHGC - Any
Proposal 1 (TGM Step 1)	U≤0.5 SHGC≤0.4		U≤0.4 SHGC≤0.55	U≤0.35 SHGC - Any
Proposal 2 (PE* + TGM)	U≤0.75 SHGC≤0.4	U≤0.4 SHGC≤0.4	U≤0.4 SHGC≤0.55	U ≤0.35 SHGC – Any
Proposal 3 (TGM Step 2)	U≤0.5 SHGC≤0.4		U ≤0.35 SHGC – Any	
Proposal 4 (PE* step 2)	U≤0.35 SHGC≤0.4			
Proposal 5 (PE* + TGM)	U≤0.75 SHGC≤0.4	U≤0.4 SHGC≤0.4	U≤0.35 SHGC - Any	
Proposal 6 (IECC +)	U≤0.6 SHGC≤0.4	U≤0.4 SHGC≤0.4	U≤0.35 SHGC–Any	U ≤ 0.32 SHGC – Any Or U≤0.35 if SHGC>0.5
Proposal 7 (Pilkington)	U≤0.75 SHGC≤0.4	U≤0.5 SHGC≤0.4	U≤0.4 SHGC–Any	U≤0.35 SHGC – Any
Proposal 8 (Simonton)	U≤0.6 SHGC≤0.4	U≤0.5 SHGC≤0.4	U≤0.4 SHGC–Any	U ≤ 0.35 SHGC – Any Or U≤0.38 if SHGC>0.5

Notes on Proposals:
Current Energy Star Program does not precisely fit the climate zones zone in Table 1. The Current Energy Star Program was modeled using the current map.

The Final Proposed Program was developed by DOE based on discussion and comments in response to the March 20, 2002 workshop.

The Original Proposed Program was developed through conversations with stakeholders in 2001 and proposed by DOE in October 2001.

Alternative Proposal 1 was developed by three glass manufacturers (TGM) and submitted to DOE in the fall of 2001.

Alternative Proposal 2 is suggested by the authors based on criteria defined in both the Proposed Energy Star (PE*) Program and the TGM proposal 1. The four zone requirements are mostly consistent with IECC's definition of climate zones but allowing for continuous zones.

Alternative Proposal 3 was developed by TGM and submitted to DOE in the fall of 2001. It is suggested as a second step after Proposal 1 change (i.e. to be implemented at some point in the future). (Note that Pella Corporation developed a proposal very similar to this except that it's U-factor requirement for <3500 HDD was 0.4; this alternative proposal is not considered in this report. Heating energy savings are slightly increased but it eliminates the use of aluminum frames completely.)

DOE considered **Alternative Proposal 4** in the summer/fall of 2001 as a Step 2 set of requirements for future adoption. Based on negative industry comments, it was decided by DOE not to further consider this proposal. It is presented in this report for the sake of completeness.

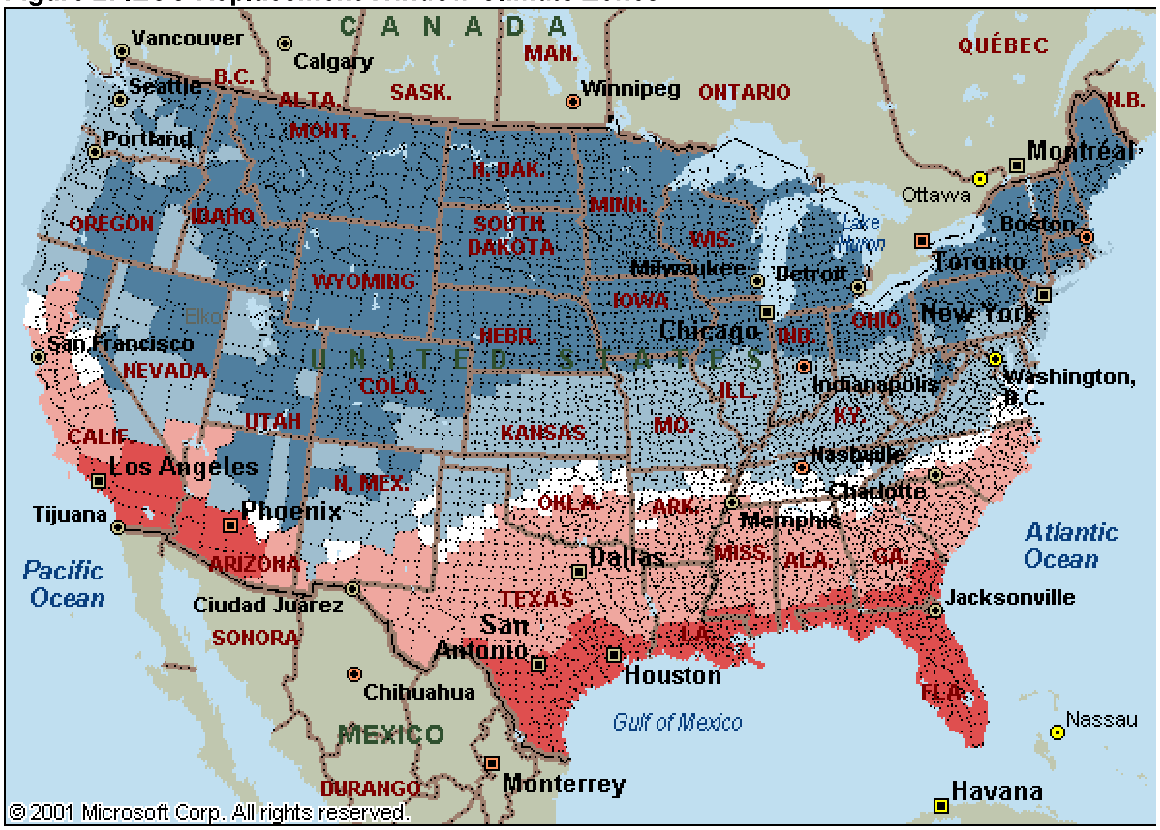
Alternative Proposal 5 is suggested by the authors based on criteria defined in both the Proposed Program and the TGM proposal 1.

Alternative Proposal 6 is suggested by the authors as a program to maximize energy savings, be mostly consistent with the IECC's definition of climate zones, and encourage all sectors of the window industry to offer improved products.

Alternative Proposal 7 was developed by Pilkington and submitted to the Department of Energy in February 2002.

Alternative Proposal 8 was proposed by Simonton Windows after 3/20/02 meeting.

Figure 2: IECC Replacement Window Climate Zones[1]



Climate Zone
■ 0 – 1,999 HDD ■ 2,000 – 3,499 HDD □ 3,500 – 3,999 HDD (For analysis, combined with 4,000 – 5,999 HDD Zone) ■ 4,000 – 5,999 HDD ■ 6,000 and above HDD

In contrast to current Energy Star's three zones, the IECC requirements are essentially for four distinct climate zones.[2] Some of the alternatives criteria combine IECC regions and create larger zones with criteria stringent enough to meet individual IECC requirements, again with modifications to the HDD contours to create continuous regions. For example, as shown in Figure 2, much of the coastal Pacific Northwest falls below 6,000 HDD, but is included in the northern region (U-value = 0.35) to maintain simplicity and still meet the IECC requirement (U-value = 0.4).

Boundaries for the Proposed Energy Star and alternative proposals were adjusted to be consistent with the existing Energy Star map philosophy of continuous zones. Figure 3 shows the approximate boundaries used to define the geographic regions for the four zone proposals.

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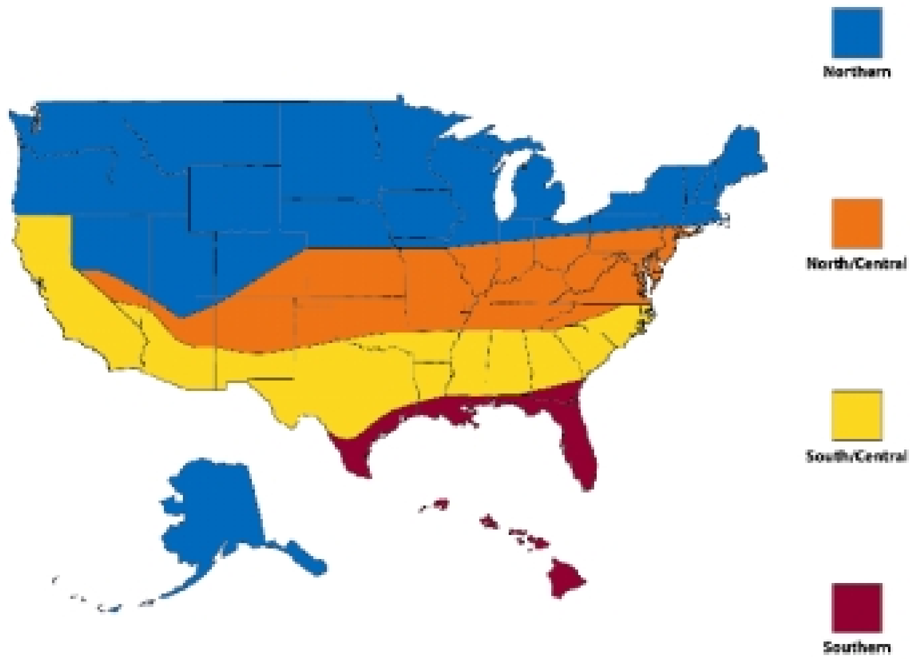
[1] 2000 IECC Section 502.2.5: Prescriptive Path for Additions and Window Replacements, and Table 502.2.5: Prescriptive Envelope Criteria Additions to and Replacement Windows for Existing Type A-1 Residential Buildings.

[2] Note that the IECC's 3,500–3,999 HDD zone has been combined with the 4,000–5,999 HDD zone given its small size and similar requirements. The entire California Central Valley was also grouped into the 2,000–3,499 HDD zone even though some cities in this climate have HDD slightly above 3,500 in order for Energy Star zoning to be consistent with California's energy code.

Figure 3: Analysis Four Zone Map



2.0 National Energy Savings

2.1 Results

The national energy savings potentials of the various proposed and alternative criteria, as well as the IECC code, were estimated separately for new construction and replacement markets, and then totaled to create an expected annual energy savings potential based on annual window sales. The two calculations and summation are an attempt to account for the relative equality, in terms of window sales, between new construction and replacements. By most estimates, new construction accounts for 45 to 50 percent of all residential window sales (in 2000, 25.9 million windows were sold into new construction and 29.3 million were sold for remodeling and replacement)[3].

The national energy impacts and savings potentials of the IECC and proposed alternatives were determined using a methodology originally developed for a similar study in 1999.[4] This procedure is based on DOE-2 building energy simulation program estimates of energy savings from windows in typical houses in 48 U.S. cities. In conducting this analysis, a couple of basic assumptions are needed:

- It is assumed all window sales move from today's efficiency distribution to the defined minimum Energy Star criteria for each zone(s) in each proposal. This is often referred to as the "technical potential."

- Energy calculations for each of the 48 cities from the NFRC 900 database[5] were averaged according to climate zones/census regions, with the average consumption and savings serving as a proxy for that climate zone/census region.

This analysis should represent a relative order of merit in terms of energy savings, but should not be interpreted as an absolute saving estimate for Energy Star windows, either current or for any of the proposed. Absolute savings will depend on many variables, such as market penetration, installed performance, future consumer energy use habits, etc.

Details on the assumptions and methodology are located in Appendix A for existing buildings and Appendix B for new construction. The accompanying spreadsheet (Appendix C) includes the assumed window characteristic and energy calculation results for the 48 cities and each proposal. Table 2 presents the results of these calculations using the regional estimated average efficiency of windows sold today as the baseline and estimating annual energy savings potential from the various proposals and IECC.

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[3] Department of Energy, Office of Building Technologies, State and Community Programs, 2001 BTS Core Databook, July 13, 2001

[4] Arasteh, D., Lawrence Berkeley National Laboratory, E. Barbour, Arthur D. Little, Inc. "An Evaluation of Alternative Qualifying Criteria for Energy Star Windows," May 12, 1999

[5] Arasteh, D., J. Huang, R. Mitchell, R. Clear, C. Kohler., "A Database of Window Annual Energy Use in Typical North American Residences." Presented at the 2000 ASHRAE Winter Meeting, February 5–9, 2000, Dallas, TX, July 1999

Table 2: Total Annual Energy Savings Potential (relative to current sales, technical potential in trillion Btus per year)

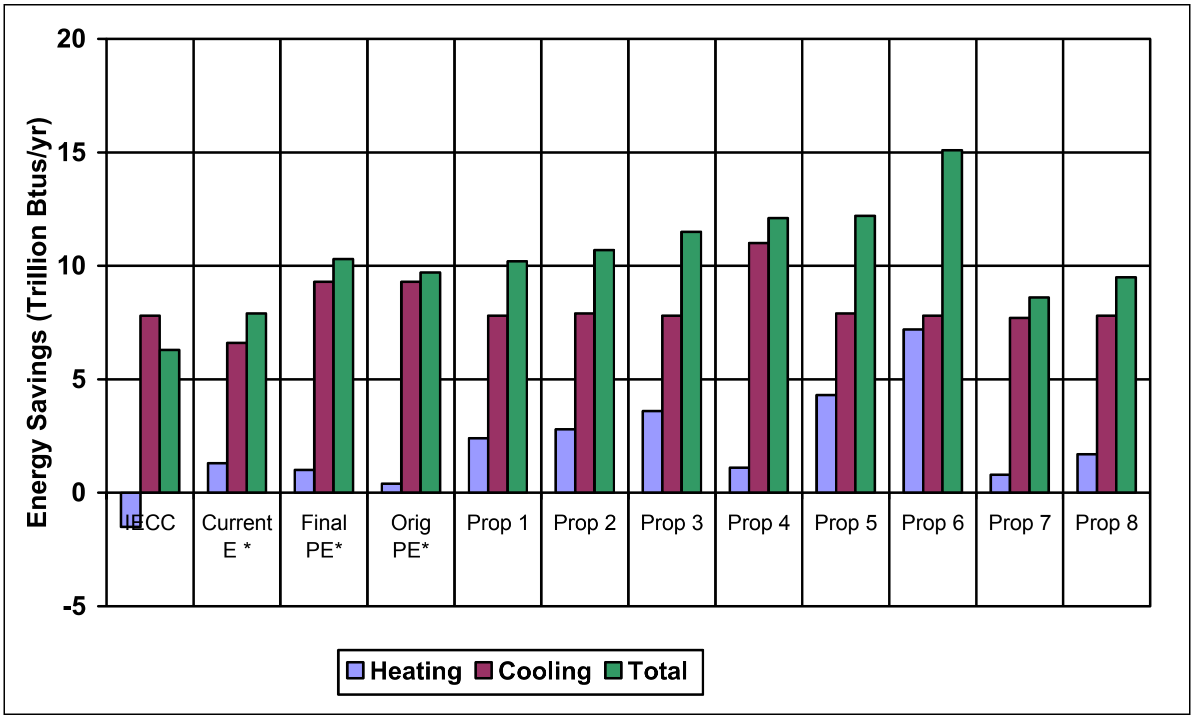
Scenario	Heating Savings	Cooling Savings	Total
IECC	(1.5)	7.8	6.3
Current Energy Star	1.3	6.6	7.9
Final Proposed Energy Star	1.0	9.3	10.3
Original Proposed	0.4	9.3	9.7
Proposal 1	2.4	7.8	10.2
Proposal 2	2.8	7.9	10.7
Proposal 3	3.6	7.8	11.5
Proposal 4	1.1	11.0	12.1
Proposal 5	4.3	7.9	12.2
Proposal 6	7.2	7.8	15.1
Proposal 7	0.8	7.7	8.6
Proposal 8	1.7	7.8	9.5

(Components may not add to totals because of rounding)

The estimated savings show greater potential with cooling than heating for all of the proposals. This is mainly due to the fact that national window sales, except in the South, have evolved from single pane to dual pane technology, which is often termed insulating glass units (IGUs). By definition, these IGUs reduce heating loads due to the lowering of thermal transmittance through the two panes of glass. Thus, an incremental change in U-value in any of the proposals will reflect lower gains in heating energy reduction than a change in SHGC, which would indicate much greater cooling energy savings. This is particularly true in southern climates (below 3,500 HDD), where there is a large amount of cooling energy savings potential. These potential cooling savings will be realized with full adoption of the IECC.

Figure 4 below shows the technical potential energy savings from all scenarios in Table 2. Total annual energy savings presented include both heating and cooling and represent savings to be gained if all windows sold in a year are converted to Energy Star products. Although this penetration rate is not realistic, it permits simple comparison among the proposals relative to the window market. These estimates do not consider the potential penetration levels which Energy Star windows are likely to achieve in the market, which will differ depending on the selected criteria. For instance, it may be reasonable to assume greater market penetration of Energy Star products if they are economically justified for the greater number of homeowners.

Figure 4: Total Energy Savings over Current Sales



2.2 General Discussion of Energy Consumption/Savings Results

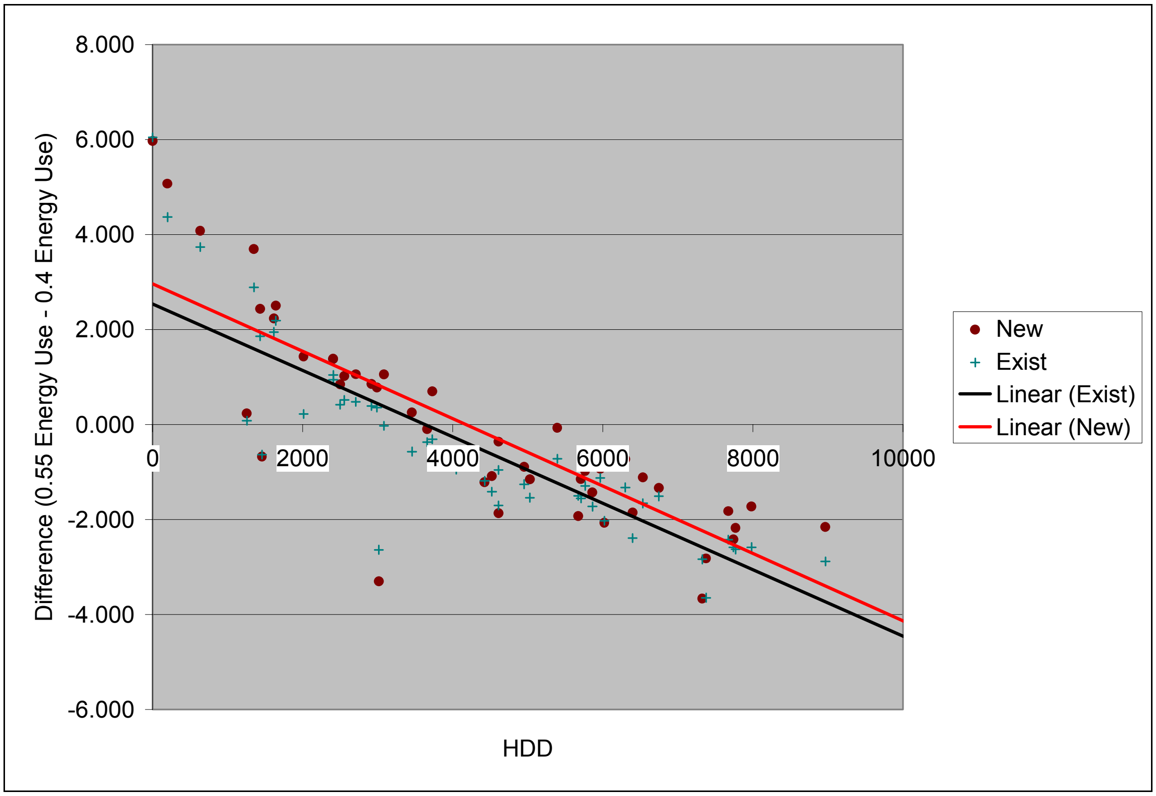
The energy impacts of windows are well known to vary with climate and application, so any efficiency-marketing program must take account of these variations. At the same time, simplicity is fundamental to Energy Star's effectiveness as a marketing program for energy efficiency. Simplicity is primarily reflected in the number of climate zones the program employs. Energy Star has been using a three-zone program. However, as our analysis shows, increased savings can result from slightly more complex four-zone programs or from simpler but more stringent one- or two-zone programs. Two particular areas for discussion, relative to the proposed criteria and energy savings, are:

- Impact of Solar Heat Gain Coefficient on Savings/Differences in the Central Zone
- New Construction Versus Existing Buildings

Impact of Solar Heat Gain Coefficient on Savings/Central Zone

One of the major differences in the various proposals is the SHGC requirement for various zones. Primarily, the discussion centers on how far to the north and at what level do you extend the maximum SHGC requirement. In order to evaluate what impact this has, we used the NFRC 900 database to estimate the relative energy consumption for a new and existing home using windows with a U-value of 0.35 and either 0.4 SHGC or 0.55 SHGC throughout the country. Below are the results of this analysis.

Figure 5: Impact of SHGC on Energy Savings, (MMBtus/yr.)



The above graph shows the relative difference in energy consumption, annual heating and cooling combined, between homes using two different SHGCs. At approximately 4000 HDD, the relative savings shifts from the low SHGC window to the higher SHGC window. This indicates the potential importance of increasing SHGC requirements in the northern climates, while still focusing on reducing U-value of windows to provide energy savings. For the northern climates, reduction in U-value will still provide the largest portion of potential savings. However, it does not take into account other considerations when developing Energy Star criteria, such as peak energy savings and trade-offs between U-value and SHGC for entire climate regions. Also, it should be noted, both of these windows will save heating and cooling energy over current sales.

New Construction Versus Existing Buildings

As stated before, the market for window sales is almost evenly split between new construction and retrofit applications. The results presented in this paper are a combination of savings from new construction and existing homes. There are a couple of differences in the estimates for new and retrofit, due to differences in each of these markets. These differences are:

- Air conditioning represents a greater percentage of total energy use in the new construction market due to increased use of insulation. The increased insulation reduces the heating load more than it reduces the cooling load. Also, new homes are far more likely to have air conditioning.

- As a national trend, new homes are located farther south than existing homes. The increased emphasis on new construction in the South has also increased related cooling consumption. In 2000, the South represented 46 percent all new homes built in the United States. Given new homes represent approximately one-half of all window sales, cooling savings and lower SHGC will be important in staving off increases in energy consumption in those regions.

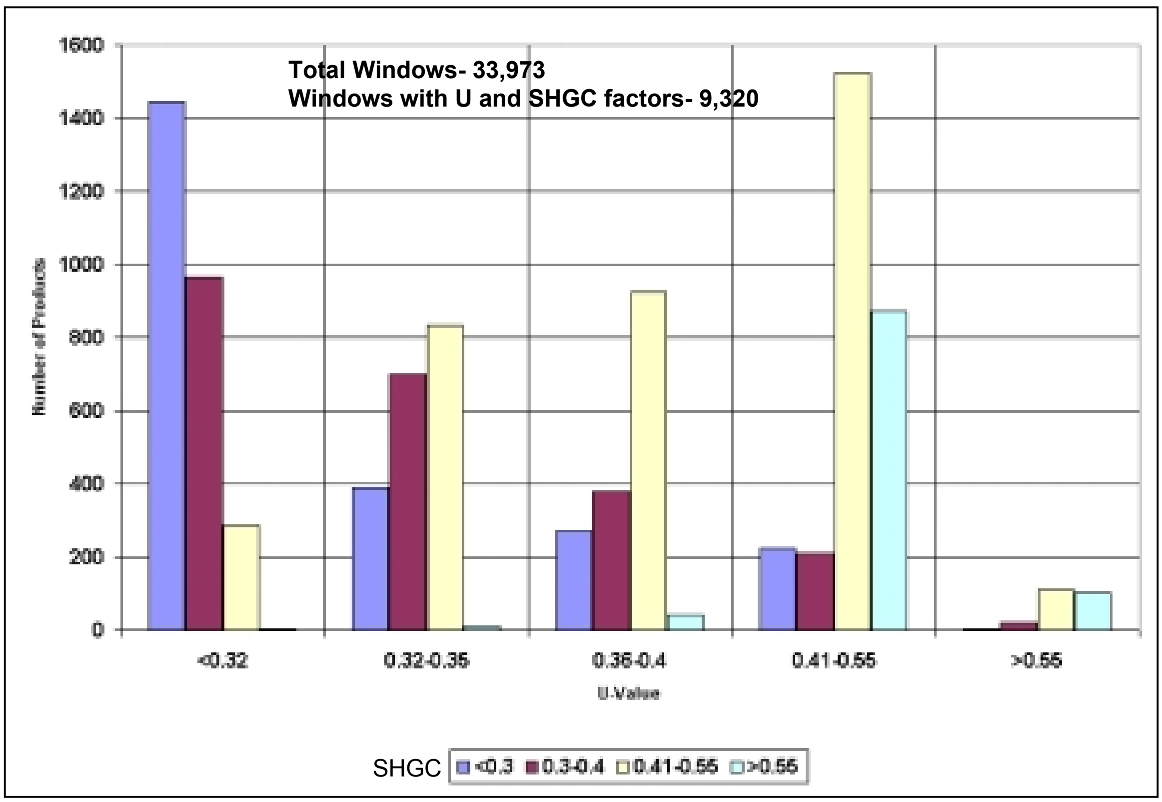
In short, and all else being equal, the new construction market will show greater energy savings for technologies that lower the cooling load. Similarly, in the existing market, technologies that lower the heating load will provide more savings. Again, details on each analysis and the various climate regions evaluated are shown in Appendices A, B, and C.

3.0 Impact on Manufacturing

Window manufacturers and consumers value the Energy Star label for identifying efficiency and comfort. Thus, the label's requirement affect window manufacturers' decisions about window components and consumers' decisions about which products to purchase. The impacts of program requirements on participants in the window market should therefore be well-understood and included as part of the final decision-making process regarding program requirements.

We reviewed a subset of the NFRC database of products (approximately 33,973 windows within certain product categories of the entire NFRC database representing over 100,000 products) to ensure that commercially available products were available for the criteria levels included in the various proposals. The products were chosen to represent the more common residential window types. This review did not address product cost, geographical availability, or manufacturing volume. In terms of number of products available, it would appear product availability is not an issue.

Figure 6: Availability of Windows by U-Factor and SHGC



Total number of evaluated windows with U-factors: 33,973
Total number of evaluated windows with U-factors and known SHGC factors: 9320 or 27 percent of the windows with U-factors
Windows evaluated include: Vertical Sliders, Casements, Horizontal Sliders, and Fixed Operable.
Source: NFRC Product Directory, 10th Edition, 2001 (web: www.nfrc.org)

Even though product availability does not appear to be an issue, there are two manufacturing sectors within the window industry where significant investments have been made and where there may be significant impacts caused by Energy Star. The impacts of Energy Star on these two sectors are addressed in this section. These sectors are:

1. Aluminum frames in the southern zone
2. Types of low-emissivity (low-e) coatings for Middle and Northern zones

3.1 Aluminum Frames

Aluminum-framed residential windows once represented a significant portion of the market (30 percent or more during the 1970s but now it is less than 13 percent). Because of the relative lower energy efficiency and lower condensation resistance of these windows in central and northern states, they are no longer acceptable under many energy codes, and consumers have moved away from these products. The lower market share of aluminum frames has been hastened by the emergence of vinyl as a cost-effective and thermally efficient replacement. The decreased market share of aluminum windows has hurt aluminum extruders more than window manufacturers; manufacturers switched to vinyl extrusions and continued to sell windows while aluminum extruders have been left without a market.

However, in several significant southern markets (Florida, the Gulf Coast States, and parts of Texas,) aluminum frames predominate. In some of these geographical regions, heating energy issues are minimal, and other non-energy issues favor aluminum products. In its Energy Star Windows program, DOE has attempted to take into account the prevalence and benefits of aluminum frames in southern markets, such as disaster resistance and traditionally lower cost.

For the <2000 HDD zone, all proposals examined had a SHGC of a 0.4 maximum; this does not affect the use of aluminum frames. Neither does the proposed maximum U-factor of 0.75 suggested in many proposals. A maximum U-factor of 0.65 would also not hinder the use of aluminum-framed low-e products and may be considered in lieu of the 0.75 requirement. A requirement of 0.65 may require some manufacturers to switch from narrow IG gaps (typical of southern climates) to wider ½" gaps (typically used in more insulating window products); such a change requires manufacturing changes but does not preclude the use of aluminum as a framing material. A lower U-factor requirement could be set if the program wanted to require thermally broken aluminum frames which reduce heat transfer by breaking the conductive path of a solid aluminum frame with a more insulating material. (Thermally breaking an aluminum frame requires changes to the manufacturing process which typically entail significant expense; in areas of the country where codes have required aluminum frames to be improved, manufacturers have often found it more cost-effective to switch to vinyl rather than upgrade to thermally broken aluminum. The added expense of upgrading to thermally broken aluminum in relation to the small energy savings that would result in this small region of the country is not considered to be effective.) Note that the new Florida energy code may set recommendations on "default" U-factors that are relatively low—this issue should be followed more closely in relation to Energy Star program requirements for this zone.

For the 2,000 to 3,500 HDD zone, U-value requirements in the IECC code have been set to a maximum of 0.5. Thus, the IECC code limits the use of aluminum frames unless thermal breaks are incorporated or there are tradeoffs against other efficiency measures in the house. An Energy Star program designed to be as or more stringent than the IECC code (see Section 4.0) would preclude aluminum frames in regions where the IECC code has not yet been adopted. In some of these regions, aluminum frames may be commonplace, so there would be an impact on local industries. However, this impact would be part of a historical trend, so the program should consider that the IECC has already set a maximum U-factor of 0.5 for this zone.

3.2 Low-e Coatings

Low-emissivity or low-e coatings are the key component used to create an efficient window or Energy Star window product. Low-e coatings are invisible, microscopically thin, metal or metallic oxide layers deposited on glass during manufacturing or soon after manufacturing. Emissivity relates to the rate of long-wave radiative heat transfer between glazing layers in a double glazed window (the lower the emissivity, the less heat transfer). This leads to decreased window U-factors (compared to uncoated clear glass) from the use of any low-e coating. Low-e coatings are all but required for an Energy Star product, so the way in which Energy Star addresses the different types of low-e coatings is critical for the low-e coating industry.

There are two manufacturing processes for low-e coatings, with each process producing a different product. Both products lead to significantly lower window U-factors but they differ in how they impact a window's Solar Heat Gain Coefficient (SHGC) – the fraction of incident solar radiation transmitted by the window. The products resulting from these two manufacturing processes are summarized below:

- Pyrolitic (sometimes called hard) low-e coatings are deposited on the glass while it is being manufactured. These coatings transmit a higher level of sunlight, which provides for added warmth in the winter but do not reduce summer cooling loads.
- Spectrally selective coatings (sometimes called soft) are applied to glass after it is manufactured using sputtering equipment. These coatings reflect the invisible part of sunlight (the solar-infrared) while still transmitting visible light. This results in "clear" looking glass with significantly reduced summer cooling loads. However, "free solar heating" during the winter is also reduced.

Spectrally selective products have become quite popular because they meet maximum U-factor requirements (for northern climates) and also maximum SHGC requirements (for southern climates). Window manufacturers find this combination appealing because they only need to stock one product that can meet or beat codes or Energy Star requirements anywhere in the U.S. Until a few years ago, several national manufacturers offered a "northern" low-e (pyrolitic) and a "southern" low-e (spectrally selective) product; these dual products have almost all been eliminated in recent years.

In central climates (the 3,500–6,000 HDD zone), both products save significant energy compared to clear uncoated double-glazing. Pyrolitic coatings save more heating energy and less cooling energy. Spectrally selective coatings save less heating but more cooling energy. In general in this region of the country, heating outweighs cooling energy use in the residential sector, but often the decision about which type of low-e product to use depends primarily on local climate and specifics of the application. However, in a good number of applications, air conditioning may be critical to energy use and comfort. In this section, we note that maximum SHGC of 0.40 in the 3,500-6,000 HDD zone could not be met by the pyrolitic low-e industry.

4.0 Consistency With Codes

Other factors that influence the selection of Energy Star qualifying criteria are external to the program. Of these factors, building codes were identified as the most important. Building codes need to be examined to see where Energy Star's requirements fall relative to the requirements in a jurisdiction. IECC 2000 and California's Title 24 Energy Code were selected as the two most important codes for comparison with the Energy Star program. This comparison was the primary factor behind DOE's efforts in 2001 to revise the Energy Star program's criteria. To date, sixteen states and the District of Columbia have adopted or are in the process of adopting the 2000 IECC or equivalent. Additionally, the 2000 IECC is viewed as the goal for many other future state codes upgrades. Table 4 presents each Energy Star proposal in relation to IECC standards. All proposals, except Proposal 1, meet California's requirements; with minor changes to the boundaries of the regions, thus Proposal 1 could meet California Title 24 requirements. Also, the alternative path for Proposal 8 in the northern region (<=0.38 U-value, SHGC >0.5) would not meet the IECC requirements.

Table 4: Current IECC Window Code Requirements and Comparisons with Proposals[6]

Reference/ Proposals	<2,000 HDD	2,000–3,499 (includes CA Central Valley)	3,500–5,999	6,000+
Current Energy Star	U≤0.75 SHGC≤0.4		U≤0.4 SHGC≤0.55	U≤0.35 SHGC- Any
IECC	U≤0.75 SHGC≤0.4	U≤0.5 SHGC≤0.4	U ≤0.4 (U≤0.5 to 3999 HDD) SHGC -	U ≤0.35 SHGC – Any
Final Proposed Energy Star	U≤0.65 SHGC≤0.4	U≤0.4 SHGC≤0.4		U≤0.35 SHGC - Any
Original Proposed	U≤0.75 SHGC≤0.4	U≤0.4 SHGC≤0.4		U≤0.35 SHGC - Any
Proposal 1	U≤0.5 SHGC≤0.4		U≤0.4 SHGC≤0.55	U≤0.35 SHGC - Any
Proposal 2	U≤0.75 SHGC≤0.4	U≤0.4 SHGC≤0.4	U≤0.4 SHGC≤0.55	U ≤0.35 SHGC – Any
Proposal 3	U≤0.5 SHGC≤0.4		U ≤ 0.35 SHGC – Any	
Proposal 4	U≤0.35 SHGC≤0.4			
Proposal 5	U≤0.75 SHGC≤0.4	U≤0.4 SHGC≤0.4	U≤0.35 SHGC - Any	
Proposal 6	U≤0.6 SHGC≤0.4	U≤0.4 SHGC≤0.4	U≤0.35 SHGC- Any	U ≤ 0.32 SHGC – Any Or U≤0.35 if SHGC>0.5
Proposal 7	U≤0.75 SHGC≤0.4	U≤0.5 SHGC≤0.4	U≤0.4 SHGC- Any	U ≤ 0.35 SHGC – Any
Proposal 8	U≤0.6 SHGC≤0.4	U≤0.5 SHGC≤0.4	U≤0.4 SHGC- Any	U ≤ 0.35 SHGC – Any Or U≤0.38 if SHGC>0.5

Exceeds IECC Code | Meets IECC Code | Doesn't meet

4.1 General Discussion of Building Codes

The IECC requirements in Table 4 apply to replacement windows. Generally, replacement values are slightly more stringent than new construction requirements. For new construction, requirements vary more widely by region. Moreover, in new construction, window U-factor requirements can be traded off against high-efficiency heating, ventilation, and air conditioning (HVAC) equipment or other energy-saving features. Code requirements for new construction also vary based on the amount of window area in the design. A true comparison of codes is therefore very complex. However, given that approximately half the products sold are for retrofits and that a large number of new construction applications would be consistent with the values presented, the quantification of current codes in Table 4 is reasonable.

A significant issue is that the IECC code has only been adopted for new construction in a few states so far; states are even less likely to adopt it for replacement windows, which are typically not regulated. Although the calculated energy savings between Energy Star and the IECC code appear small, the differences between current sales and Energy Star are, in fact, significant because the IECC code is far from being widely adopted. It is expected that an Energy Star program, which is equal to or slightly ahead of the IECC code for the next few years, will help make the transition to full adoption of the IECC less difficult for the window industry and builders.

Regional issues and state policies affect codes. In states with similar climates, significant differences in codes may exist because of local policies. In addition, the penetration of Energy Star windows varies from area to area—it is, for example, much greater in the north than in the south, so the effort required to move a significant portion of sales to an Energy Star level in some portions of the country will vary.

[6] IECC does not address SHGC for areas above 3,500 HDD. Proposals that include SHGC requirements above 3,500 with equivalent IECC U-value are shown not to exceed code.

5.0 Energy Supply Issues

Electricity reliability and gas pricing in times of high demand should also be considered in the decision making process about Energy Star requirements although these issues are often regional and temporal. Taking these factors into account consistently requires clarifying the perspective upon which the Energy Star criteria is or should be based. Solar heat gain through windows is a large component of residential cooling loads; therefore, reducing the SHGC of windows will reduce peak-cooling loads dramatically, which in turn reduces electricity consumption, utility bills, and power-plant pollution emissions.

Since the proposals were mostly similar except for the central region, a preliminary evaluation was made for that zone where the SHGC varied significantly among proposals. The zone with HDD more than 3,500 but less than 6,000 typically included differing levels of SHGC, either a maximum of 0.4 or a maximum of 0.55. Previous studies, such as *Energy Savings and Pollution Prevention Benefits of Solar Heat Gain Standards in the International Energy Conservation Code*[7] examined the peak impacts of adopting a 0.4 SHGC in the warmer climates (less than 3,500 HDD).

To examine the 3,500 to 6,000 HDD zone, we used the NFRC 900 database to calculate the average reduction in peak demand between windows with SHGCs of 0.55 and 0.4. Using the assumption that when windows were replaced, the two options available to the homeowner would be between windows whose SHGCs were either 0.4 or 0.55, we calculated a maximum net total potential peak reduction between these two options. The savings are based on the selection of windows with a 0.4 SHGC instead of windows with a SHGC of 0.55. Also, it was assumed the entire stock of windows would be replaced in 40 years. The results of this calculation are as follows:

Table 5: Annual Peak Reduction for 3,500 to 6,000 HDD

Climate Zone 3,500 to 6,000 HDD	
Average Peak Reduction per Home	0.25 kW
Number of Homes With Cooling	26.2 Million[8]
Total Reduction	6,550 MW
Typical Lifetime of Windows	40 years[9]
Annual Avoided Capacity	164 MW[10]

The 6,550 MW total reduction represents the total potential reduction in peak load for existing homes using cooling in this climate zone. Assuming that windows are replaced every 40 years, this would equal the equivalent of displacing one 164-MW power plant every year; for comparison the average size of coal plants operating in 1998 is 272 MW[11]. In reality, under a 0.55 maximum SHGC scenario, many products with SHGCs of 0.4 or

[7] Prindle, Bill and Dariush Arasteh, "Energy Savings and Pollution Prevention Benefits of Solar Heat Gain Standards in the International Energy Conservation Code," May 2001
[8] Energy Information Administration, 1997 Residential Energy Consumption Survey, http://www.eia.doe.gov/residential.html
[9] Average window life span is 35 to 45 years, BTS Core Databook, 2001
[10] For comparison, the previous study cited in footnote 2 noted savings of 466 MW annually for new and existing window sales through adoption of the IECC in 10 southern states.
[11] Energy Information Administration, Inventory of Power Plants in the United States 1999, November 1999

lower would also end up being installed (since they also meet the criteria). Thus, some of the 164MW savings would be expected to be realized with the 0.55 maximum.

Peak energy savings have other impacts beyond the need for new power plants. Peak reduction has the potential to impact, positively, energy prices, pollution reduction and electric system reliability. Examining forecasts for energy prices has many regional variances. Development of a methodology to evaluate electricity pricing, impact on generating capacity and reliability is part of an ongoing Appliance Standards Rulemakings. Air pollution impacts are also a factor to be considered in relation to Energy Star requirements. Typically, saving on electricity (cooling) reduces air pollution impacts more than savings on gas (heating).

6.0 Conclusions

Several, often conflicting, issues need to be addressed in the development of an updated Energy Star windows program. This report notes these issues and the tradeoffs among them, to aid DOE in its decision-making process.

These issues are:

- Energy savings from the program
- Simplicity of the program
- Consistency of the program with IECC Codes and regional issues
- Impacts of the program on specific manufacturing sectors
- Impacts of the program on energy supply

The following table summarizes the author's assessment of the advantages and disadvantages of the various Energy Star Proposals given the above list of issues.

Table 6: Summary Evaluation of Proposals

Proposal	Advantages	Disadvantages
Final Proposed Energy Star	• Provides energy savings over IECC codes and current Energy Star • Maintains relative simplicity of the existing system (3 zones) • Summer peak demand savings (eliminating the need for construction of some new power plants)	• Affects one manufacturing sector (pyrolitic low-e)
Original Proposed	• Maintains relative simplicity of the existing system (3 zones) • Summer peak demand savings • Provides energy savings over IECC codes and current Energy Star	• Affects one manufacturing sector (pyrolitic low-e)
1: TGM Step 1	• Maintains relative simplicity of the existing system (3 zones) • Provides energy savings over IECC codes and current Energy Star	• Affects one manufacturing sector (Aluminum products) • Requires small modification of climate zones definition to meet California Title 24
2: PE* + TGM	• Provides energy savings over IECC codes and current ENERGY STAR • Adds a fourth zone, which allows for consistency with the four IECC zones	• Adds fourth zone, which increases complexity
3: TGM Step 2	• Provides savings over IECC codes and Current Energy Star • Increases simplicity by having only two zones	• Affects one manufacturing sector (Aluminum products) • Has disparate requirements for north (easy to meet) and south (hard to meet)
4: PE* Step 2	• Provides energy savings to IECC codes and current Energy Star • Simplicity from only one zone • Summer peak demand savings	• Strongly affects pyrolitic low-e manufacturing sector • Affects aluminum product manufacturing sector • Disparity in requirements between North (easy) and South (hard) • Overwhelmingly negative reaction in 2001 from window industry
5: PE* + TGM	• Provides energy savings to IECC codes and Current Energy Star	• Negative reaction from window industry concerning the elimination of metal clad wood windows from central region
6: IECC+	• Provides energy savings to IECC codes and Current	• Adds fourth zone, which increases

	Energy Star • Requirements exceed those of the IECC code in all regions • Adds fourth zone, which allows for consistency with 4 IECC zones	complexity
7: Pilkington	• Provides energy savings over IECC codes and current Energy Star • Adds fourth zone, which allows for consistency with 4 IECC zones	• Adds fourth zone, which increases complexity
8: Simonton	• Provides energy savings over IECC codes and current Energy Star • Adds fourth zone, which allows for consistency with 4 IECC zones	• Adds fourth zone, which increases complexity • Alternative path for northern climate zone is not consistent with IECC

APPENDIX A

Existing Building Methodology and Results

Data from the NFRC 900 database of DOE-2 runs for 48 U.S. climates was regressed against U and SHGC [Arasteh, D., J. Huang, R. Mitchell, R. Clear, C. Kohler. July 1999. "A Database of Window Annual Energy Use in Typical North American Residences." Presented at the 2000 ASHRAE Winter Meeting, February 5-9, 2000, Dallas TX and published in the proceedings.] A specific regression was developed for each climate. These regression expressions allowed estimates of the annual energy impacts from small changes to Energy Star window properties. Heating Loads reported by DOE-2 were translated into electric resistance heating energy using an efficiency of 1.0 and into heat pump energy using an approximate coefficient of performance (COP) of 2.0. Given the baseline windows inputs for each city, the spreadsheet calculates the heating and cooling energy consumption of a typical residence. Next, the window performance criteria of the current program or one of the proposals is input for each city, and the spreadsheet recalculates the energy consumption for the same house. The ratio of the energy consumption under the proposal to that under the baseline indicates the energy savings realized for both heating and cooling.

A correction factor was applied to the savings estimates to account for the fact that the regression expression developed above was developed for windows applied to typical new construction, as opposed to typical existing construction. This correction factor varied with climate, but typically reduced heating energy savings 20–30 percent and typically reduced cooling energy savings 10 percent. This correction factor accounts for the estimated decreased levels of insulation and air-sealing in the envelope of existing buildings. Note the absolute energy savings from windows are generally higher in retrofit applications but the fractional savings (window to whole house) are less since the absolute energy savings in existing houses is proportionally greater than energy use in typical new houses. This correction factor was determined by comparing two databases on energy impacts of windows, one for typical new and one for typical existing homes developed for the NFRC Annual Energy Rating Subcommittee (see http://windows.lbl.gov/AEP/database.htm).

For each of the proposal climate zones, heating and cooling energy use for the proposed Energy Star criteria were determined using weighting factors for space heating and cooling based on a comparison of RECS space heating and cooling energy by HDD zones to NFRC 900 data. Shares of electricity, natural gas, and oil demand were determined from RECS, which provides household gas and electric heating and cooling consumption data for each climate zone. The national energy consumption data are provided in the following table. The correction factors developed were used to provide a savings estimate, in percentage reduction, for heating and cooling of existing buildings. This percentage reduction for each of the climate zones was then multiplied by the actual estimated RECS heating and cooling energy use.

Table A.1: RECS Annual Energy Consumption

Energy Use (Quads)				
Climate Zone	**Heating**			**Cooling**
	Gas	**Electric**	**Oil**	**Electric**
<2,000 HDD	0.22	0.17	—	0.55
2,000–3,499 HDD	0.41	0.23	0.02	0.30
3,500–5,999	1.30	0.67	0.52	0.36
6,000–7,000	1.23	0.17	0.22	0.09
7,000 +	0.62	0.06	0.26	0.04

Source: 1997 Residential Energy Consumption Survey

The Existing Buildings results were converted to annual savings, relative to current sales by assuming 40-year lifetime for windows. Below are the results of this analysis:

Table A.2: NFRC 900—RECS Results (relative to current typical sales, technical Potential in trillion Btus/year)

Scenario	Heating Savings	Cooling Savings	Total
IECC	(1.08)	4.00	2.92
Current Energy Star	0.33	3.55	3.88
Proposed Energy Star	0.73	4.95	5.69
Fall 2001 Proposed	0.30	4.95	5.25
Proposal 1	1.83	4.00	5.83
Proposal 2	1.78	4.09	5.87
Proposal 3	2.57	4.05	6.62
Proposal 4	0.62	6.07	6.69
Proposal 5	2.7	4.09	6.79
Proposal 6	4.70	4.08	8.78
Proposal 7	0.69	3.99	4.68
Proposal 8	1.35	4.00	5.35

(Components may not add to totals because of rounding)

Appendix B

New Construction

Data from the NFRC 900 database of DOE-2 runs for 48 U.S. climates was regressed against U and SHGC [Arasteh, D., J. Huang, R. Mitchell, R. Clear, C. Kohler. July 1999. "A Database of Window Annual Energy Use in Typical North American Residences." Presented at the 2000 ASHRAE Winter Meeting, February 5-9, 2000, Dallas TX and published in the proceedings.] A specific regression was developed for each climate. These regression expressions allowed us to estimate the annual energy impacts from small changes to Energy Star window properties. Heating Loads reported by DOE-2 were translated into electric resistance heating energy using an efficiency of 1.0 and into heat pump energy using an approximate coefficient of performance (COP) of 2.0. Given the baseline windows inputs for each city, the spreadsheet calculates the heating and cooling energy consumption of a typical residence. Next, the window performance criteria of the current program or one of the proposals is input for each city, and the spreadsheet recalculates the energy consumption for the same house. The ratio of the energy consumption under the proposal to that under the baseline indicates the energy savings realized for both heating and cooling.

Using the heating and cooling loads developed from the NFRC 900 database; the average consumption from each census region was multiplied by the number of homes built per census region. This provides a total expected consumption under each scenario. Table B.1 shows are the numbers of single-family homes built in 2000.

Table B.1: Number of New Homes Built in 2000

Census Region	Number of Homes Built, (000s)
New England	38.7
MidAtlantic	83.6
East North Central	173.2
West North Central	72.2
South Atlantic	331.5
East South Central	60.7
West South Central	137.6
Mountain	148.7
Pacific	152.0

Source: US Census Bureau

The heating results are weighted relative to the current penetration of natural gas, fuel oil, and electrically heated new homes. This data are shown below:

Table B.2: Type of Heating Fuel in New One-Family Houses in 2000

Census Region	Natural Gas (%)	Oil (%)	Electric (%)
Northeast	65	28	6
Midwest	92	—	7
South	50	—	50
West	91	—	8

Source: U.S. Census Bureau (components may not add to 100% because of rounding)

This type of analysis is heavily dependent on the quality and type of data used to develop the energy savings. Unfortunately, the U.S. Census Bureau does not report new construction statistics by climate regions, reporting instead by Census Regions. Aggregating the results to nine census regions leads to averaging multiple climate zones into one region. Such aggregation leads to a larger uncertainty for the new construction analysis compared to the previous existing building's analysis, which was based on RECS.

The one change in methodology from the existing building calculation is: instead of applying these results to RECS data, the average savings for each proposal from the NFRC 900 database for each census region was applied to the annual total number of residential single-family sales in each region. Table B.3 presents the results, compared to the current typical sales.

Table B.3: NFRC 900—New Construction Results (relative to current sales, technical potential in trillion Btus)

Scenario	Heating Savings	Cooling Savings	Total
IECC	-0.38	3.76	3.38
Current Energy Star	0.94	3.08	4.02
Proposed Energy Star	0.28	4.32	4.61
Fall 2001 Proposed	0.12	4.32	4.44
Proposal 1	0.56	3.76	4.32
Proposal 2	1.01	3.80	4.81
Proposal 3	1.06	3.79	4.85
Proposal 4	0.49	4.93	5.41
Proposal 5	1.57	3.80	5.37
Proposal 6	2.54	3.75	6.30
Proposal 7	0.13	3.75	3.88
Proposal 8	0.38	3.76	4.14

(Components may not add to totals because of rounding)

Appendix C

The accompanying spreadsheet serves as Appendix C for the analysis. Some notes on Inputs/Tables in the spreadsheet:

- Heating Energy is expressed in MMBtu/yr.
- Cooling Energy is expressed in kWh/yr.
- Sales Scenario estimated using the report *The National Energy Requirements of Residential Windows in the U.S.: Today and Tomorrow*, Frost K., Eto J., Arasteh D., and Yazdanian M., March 1996 ACEEE 1996 Summer Study on Energy Efficiency in Buildings: "Profiting from Energy Efficiency," August 25-31. 1996, Asilomar, Pacific Grove, CA.